How can a robot signal its incapability to perform a certain task to humans in an acceptable manner?

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***Abstract*— In this paper, a robot that is using politeness to overcome its incapability to serve is presented. The mobile robot ”Alex” is interacting with human office colleagues in their environment and delivers messages, phone calls, and companionship. The robot's battery capacity is not sufficient to survive a full working day. Thus, the robot needs to recharge during the day. By doing so it is unavailable for tasks that involve movement. The study presented in this paper supports the idea that an incapability of fullfiling an appointed task can be overcome by politeness and showing appropriate behaviour. The results, reveal that, even the simple adjustment of spoken utterances towards a more polite phrasing can change the human's perception of the robot companion. This change in the perception can be made visible by analysing the human's behaviour towards the robot.**

I. INTRODUCTION

In the past years more and more focus has been spent on how we can create robots that can accompany us in our daily life. Following this trend there are many difficulties to overcome to make this happen. But there are no perfect solutions out there. In fact, the complexity of our world makes it highly unlikely to find all solutions to all of a robot's shortcomings. But we humans can always solve problems ourselves and this is socially accepted. But overall, robots will require sustainable social intelligence to accompany humans in their daily life [1]. In this paper, we like to focus on the behaviour a robot should present given the fact it is not capable to fullfill a certain task.

One solution presented by humans for indisposedness is to use a polite apology[2]. Following in the footsteps of human behaviour has been proposed as a good starting point to create appropriate robotic behaviour [3].

A study by Min Kyung [4] indicated breakdown in robotic service had severe impact on evaluations of the service and the robot, but forewarning and recovery strategies reduced the negative impact of the breakdown. They also found that an apology strategy was effective in making the robot seem more competent, making the participants feel closer to and liking the robot more.

Furthermore, being polite is important to create a social order and it is a precondition of human cooperation [5]. It is proposed here that if a robot is obedient rather than leading it is more likely to be accepted and be forgiven for its incapabilities. The concept of being responsive in an appropriate way rather than being self-determined has been shown to create a higher contingency in a human robot interaction [3].

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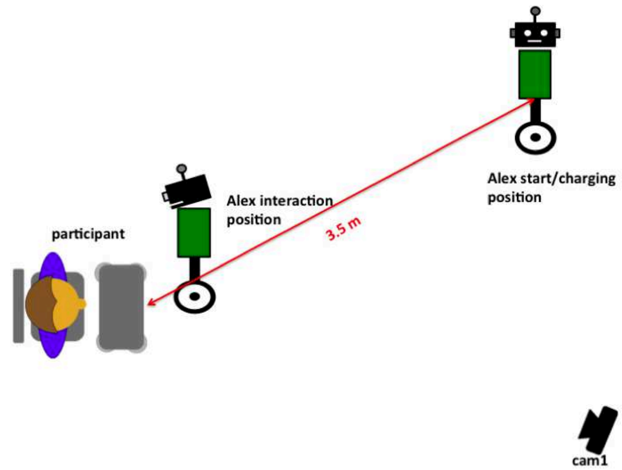

Fig. 1. In this figure you can see the experimental setup. One camera is used to observe the scene and the mobile robot ”Alex” can move between the desk and it starting/charging position.

Hence, can a rephrasing of the utterances spoken by a robot into a more polite and apologetic manner already influence the human perception of this robot? It has been shown that language can have an immediate and strong influence onto a human robot interaction, and the used words can be impacted on many different levels through social signalling strategies [6], [7].

A particular study by Syrdal et al. [8], examined the role of spatial behaviours in building human-robot relationships in a long-term HRI study. The two robots used in the study had similar interaction and expressive capabilities, but only one robot was capable of moving and other robot was stationary. Participants reported feeling closer to the robot capable of physical movement and rated it as more likeable against a stationary robot.

There has been very little research in the area of power management in social robotics domain. The existing techniques currently are mostly implemented on hardware or software level. Wei Zhang [9] studied an approach to minimise the power consumption of a mobile robot by controlling its travelling speed and the frequency of its on-board processor simultaneously. ASPEN system by NASA, has been applied to automated sequence generation for rovers and is also being use for onboard planning for rovers and power management [10]. However, there is no solution yet to accomplish a sufficient power management in the domain of social robotics. We propose that social robots need social intelligence to learn and adapt to social requirements to manage their power

behaviour.
In this paper, a human robot interaction study is presented, where a robot tries to overcome its incapability to fullfill its appointed tasks a full day long – out of the fact that its battery capacity is not sufficient to do so – by being polite and apologising for its shortcomings. Therefore, a Wizard of OZ scenario in a office space scenario was explored with 10 human participants.
The target of the analysis is to strengthen or disprove the following Hypotheses:

H1: If the robot can mitigate disappointment due to failure to perform a task then it would be more acceptable to humans

H2: If the created social order by using politeness is acceptable for the human it will comfort him/her in the interaction with the robot

II. Experiment

The robot Alex is a companion to the participants in this experiment, while they are marking exams. They have been appointed by Professor Bob to mark one exam, which he had forgotten before leaving for his holidays. They are instructed to mark the exam by comparing it with the answer sheet provided.
During the scoring the participants are not only accompanied by Alex, but he is also assisting the user by giving further information left as notices from a colleagues, deliver phone calls and an interface to communicate. The overall setting of the experimental space can be seen in Figure 1 .

A. *Robotic platform*

The robot (Pioneer P3AT refer Fig. 3) with enhanced superstructure is equipped with a laptop PC, navigation system, distance sensors, kinect, camera and an expressive head EMYS [11] used to express its internal emotional state (Happy, Sad, Neutral). The team buddy can navigate to users' desks to interact and perform tasks, it has text-to-speech capabilities, the robot has no speech recognition so users can interact with the robot using a web based android tablet interface. The robot has 6 lead acid batteries (12V, 7Ah each) offering an approximate operational time of 3 hours when fully charged (depending on usage) and require about 3 hours to recharge. Considering the long recharge time and that the robot has to perform several tasks every day, there is an urgent need for a power management strategy.

B. *Procedure*

The participants were given an instructions sheet to read before entering the room.
We are researchers working in the lab you are about to enter. There is a robot, the Team Buddy Alex, an office assistant robot that helps us in the lab. TB cannot hear you but you can talk with Alex using a tablet placed on the body, although using the tablet is optional.
The robot can perform tasks like greeting, passing messages left by other team mates and deliver calls (Please note when you hear phone ring, this is not a real phone call and you can answer using the tablet by pressing Yes/No button)
Bob and Paul are professors at this university who work together in the Lab you are entering. Bob is now on holiday and needs to mark some exams. He has forgotten one in the lab and has asked you to do that for him.

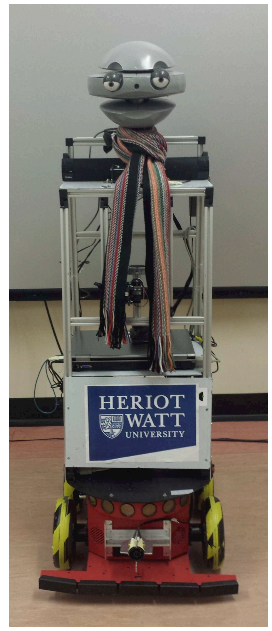

Fig. 3. Team buddy Alex the robot.

A participant entered into a room (4.5m×6m, Figure 2) and was asked to mark an exam paper seated on a desk (an answer key was provided to the participant). The wizard could control the robot's movement and speech using a GUI based wizard interface. A webcamera was placed in the corner of the room through which wizard could have the full view of the room. The experiment had two conditions. The first session (Part A) was the same for all participants, although the participants were not aware that the experiment has two sessions. The TB greeted them initially and then performed two tasks namely message delivery and call delivery after fixed time intervals of 2 minutes. The tasks involved the robot navigating from a starting location in the room to user's desk and then performing a verbal action using an artificial synthesised voice. Although the robot has expressive capabilities, there were not used in this particular study to avoid biasing the results.
After performing the Part A, the participant came out of the room and answered the first part of the questionnaire and then were sent back to the room being asked to try to imagine that some time has passed between first part (morning time) and now (evening). Furthermore, they were asked to mark Part B of the exam paper. In the Part B, second part of the experiment, the robot performed the same 3 tasks (greet, message, call) from a recharge position in the room, the robot was facing the wall during the second part. In Part B, there were two conditions:

1) the first condition was the neutral condition where the robot was using the same verbal communication as Part

Fig. 2. Experiment room: Part A (left: moving TB), Part B (right: stationary TB while recharging)

A for all tasks except for the greeting,

2) in second condition, the robot was apologetic and provided more explanation about its situation and its limitation for not being able to move due to recharging activity.

Examples of the verbal communication are stated in Table I. Participants were randomly assigned to one of the two conditions. So 5 of the participants interacted with an Apologetic robot and 5 of them interacted with the neutral robot in Part B. The total interaction took around 10 minutes for each part depending on how long it took the participant to mark the exam paper. After the second session Part B, the participant was again asked to fill in the second part of the questionnaire.

When the participants tried to have a conversation with the robot using the tablet interface placed on the robot, the robot responded by saying “Sorry my responses are limited, I didn’t understand you”. These responses were deliberately fixed to elude the participant from having any false sense of intelligence from the robot.

C. Design

The experiment is designed as a 2X2 setup (see Fig 6). Thus, there is not only the possibility to validate between subjects, but also inside one subject. For this small scale experiments, the inter-person variability is usually very high, as it is also in our case. Therefore, it is important to have the changes to validate within one subject.

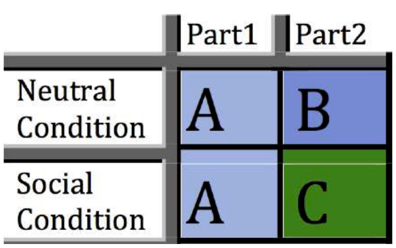

Fig. 4. 2X2 setup

D. Participants

10 participants participated in this experiment. 5 participants were randomly assigned to each condition. There were 3 female, 2 male participants in the social condition, and 2 female and 3 male in the neutral condition. The participants were recruited from the University from different departments.

Task	**Part A or Part B (Neutral)**	**Part B (Apologetic / Polite)**
Greeting	Part A: Hello, good morning. I am the Team Buddy of this lab. My name is Alex, i cannot hear you, so please use the tablet placed on me, to talk with me, hope you have a good day. My battery is fully charged Part B (Neutral): Good evening, good to see you back. My battery is low, so i am recharging now, if you want to talk with me then use the tablet placed on me	Good evening, good to see you back, sorry my battery is low, so i am recharging now, I cannot come there, but if you want to talk with me then please use the tablet placed on me
Message	There is a message left by Paul. You need to mark the exams Part A, If you want to reply please use the tablet placed on me	There is a message left by Paul. You also need to mark the exams Part b. Sorry I am recharging so I cannot come there, but if you want to reply please use the tablet placed on me
Message Reply	I got your message for Paul and will deliver it when i see him	I got your message for Paul and will deliver it when i see him, thank you
Phone Call	There is a call for you, please use the tablet to answer the call	There is a call for you. Sorry I am recharging, so i can’t come there, please pick up the tablet placed on me to answer the call

TABLE I
VERBAL COMMUNICATION

III. DATA ANALYSIS

For a first data Analysis we used an annotation tool which has been developed by Chrsitian Dondrup and Katrin Lohan. This tool called ManGA (Manual Gaze Annotator) was originally developed to annotate gaze direction in videos. But the tool can be used for all sort of timebased location

annotation on videos (2D). In this paper i.e. we used it to annotate the movement from both the human and the robot. Further details about this tool and how the annotation was carried out you can find in sec III-A.
In a second step ELAN was used to annotate intervals of speech and motion for both human and robot. This annotation was carried out to research the multimodal interplay of the interaction. Further detail can be found in sec III-B.
Finally, all annotations were analysed by using Matlab. Further detail can be found in sec III-C.

A. ManGA Annotation

ManGA annotations were carried out for the movement of the robot as well as the movement of the participant. The approximation for the 2D location was the balance point of the body of the participant and the balance point of the robot were collected for each frame of the video (25 fps). The features of ManGA allow frame by frame annotation as well as the possibility to refine the grid size. Here a 10X10 grid was choose. This translate back to real world measurement of 0.5 m X 0.5 m per square. ManGA can display videos on

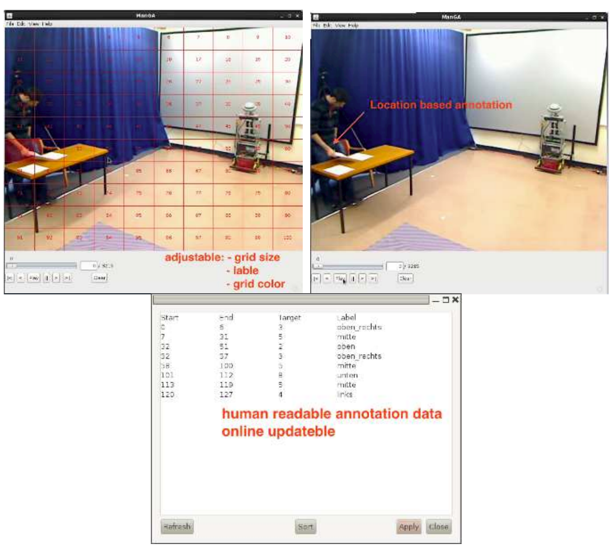

Fig. 5. The ManGA tool.

a frame by frame basis or display in the video in the given speed (i.e. 25 fps). As mentioned before, the annotation grid can be adjusted in terms of the mesh scale to generate a higher or lower accurateness of the location annotation. The labels of each grid square can be adjusted and a template annotation can be stored. The resulting text file containing all annotations made can be viewed during the annotation and adjustments can be made online. The resulting annotation file is human readable and easy to import in other tools.

B. ELAN Annotation

For the ELAN annotation the following description rules were created and followed [12]. The highlighted rules are the ones which have been taken into account for the final analysis.

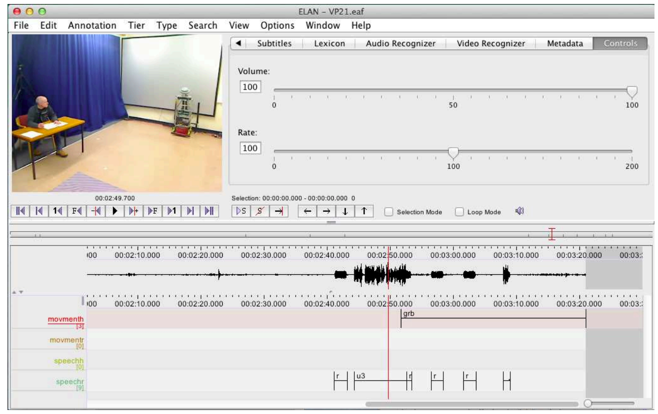

Fig. 6. ELAN annotation screen.

Annotation rules:

tier: movement h:
sd = siting down
gtr = getting tablet from r
btr = bring tablet to r
gr = going to robot not picking up tablet
gu = getting up
grb = going to robot not picking up tablet and back to the desk
grbn = gdb but no interaction with the tablet

tier: movement r:
s2i = start to interaction pos
i2s = interaction to start pos

tier: speech h
spoken utterances

tier: speech r
u1 = greeting
u2 = message
u3 = call
r = phone ring
utterance = if not u1-u3 and not r

C. Analysis

The annotation data was imported into Matlab [13]. Based on the data generated with ManGA we calculated the distance δ_{rh} between the human and the robot for each frame of each participant. Based on the mean values of δ_{rh} for each participant part A and part B, for each condition, an One-Way ANOVA was performed (were n is the number of participants for each condition).
Furthermore, also the ELAN annotations were imported into Matlab. Based on the annotated time intervals of the human movement (tier movement h) and the annotated intervals for the spoken utterances presented by the robot (tier speech r), the 'reaction time' has been calculated. Therefore, the mean timespan from $U2_r$ is the end of the annotated interval of

the spoken utterance of the robot to deliver the message until the start of the annotated interval following this utterance and presenting a response to it (i.e., 'gtr', 'gdb', 'gr'), as well as the the timespan from $U3_r$ is the end of the annotated interval of the spoken utterance of the robot to deliver the call until the start of the annotated interval following this utterance and presenting a response to it (i.e., 'gtr', 'gdb', 'gr'), has been calculated.
On the 'reaction time' of the participant a One-Way ANOVA between Part A and B has been carried out. Moreover, a One-Way ANOVA between Part A and B for the social condition has been carried out based on the timespan from $U3_r$ is the end of the annotated interval of the spoken utterance of the robot to deliver the call until the start of the annotated interval following this utterance and presenting a response to it (i.e., 'gtr', 'gdb', 'gr'). This was done to further evaluate on the interplay between the robot dements and the human motion.

IV. Results

In this section, the results of the participants' behaviour, based on the annotations created will be presented. First, the distance in the movement between the robot and the human will be examined carefully. Secondly, the response to the robots demands presented by the delivered massage and the delivered call of the human are taken under the microscope.

A. ManGA results

Resulting from the ManGA annotation which was post processed with Matlab as described above, a One-Way ANOVA between Part A and B for each condition was performed. For the social condition a significant difference between part A and B can be reported F(1, 8) = 10.2 , p = .013. These results present that the participants spent more time closer to the robot in part B than in part A. Furthermore, in the neutral condition the results of the One-Way ANOVA between Part A and B are highly significant F(1, 8) = 11.82 , p = .009. As shown in Fig. 7 and Fig. 8, in contrast to the social condition the participants in the neutral condition tend to stay shorter near the robot and even than further away from the robot in part B than in part A. These results support our Hypothesis that if the robot is polite and apologetic in its behaviour participants will accept it better, and will feel more comfortable in its company.

B. ELAN results

Based on the ELAN annotation described above the reaction time of the participants on the robots utterances were calculated. In detail, the timespan between the end of the utterance where the robot is delivering the massage and the moment when the participant stands up to answer was calculated. Furthermore, the timespan between the end of the utterance where the robot is delivering the call and the moment when the participant stands up to answer it was calculated. For each participants a mean 'reaction time' for both robots utterances was calculated. The mean timespans can been seen in Fig. 9 and Fig. 10. Hence, a One-Way ANOVA was carried out between Part A and B with in each condition, in the social condition F(1, 8) = 3.558, p = .096, and the neutral condition F(1, 8) = .838, p = .387 there were no significant differences between part A and B. Furthermore the trend in the social condition in the mean can be strengthened by an even stronger trend in comparing only the timespan between the end of the calling utterance of the robot and when the human stands up. The One-Way ANOVA resulted in F(1, 8) = 4.412 , p = .069. Also, the trend can be identified in Fig. 9 in the contrast between the orange points vs the blue points.Therefore, this result proposes the point that participants in the social condition took more time to respond to the call then in the neutral condition. At a first look this could appear as a negative result for our attempt to make the robot more acceptable for the human, as the people are taking more time to reply to the robot when it is behaving more politely. But considering the fact that the human is performing a task, one could also consider this as a very positive result, as the humans don't feel obliged to respond to the robot urgently. The fact that the result is not significant is to our opinion due to the fact that the group we are testing is too small. In the future we will have more participants, on the same experiment and a more elaborate test will be performed.

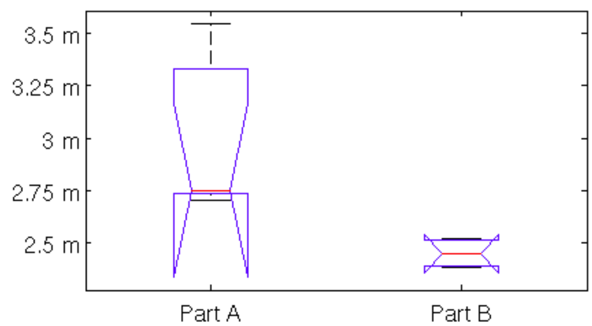

Fig. 7. Social Condition

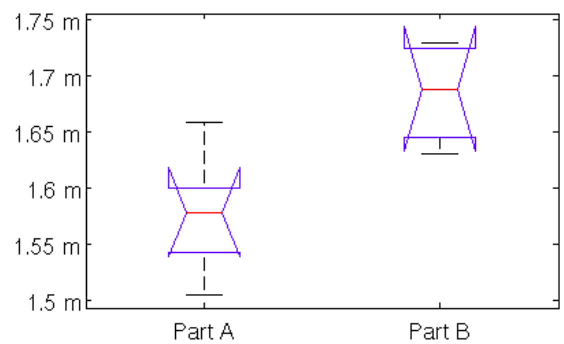

Fig. 8. Neutral Condition

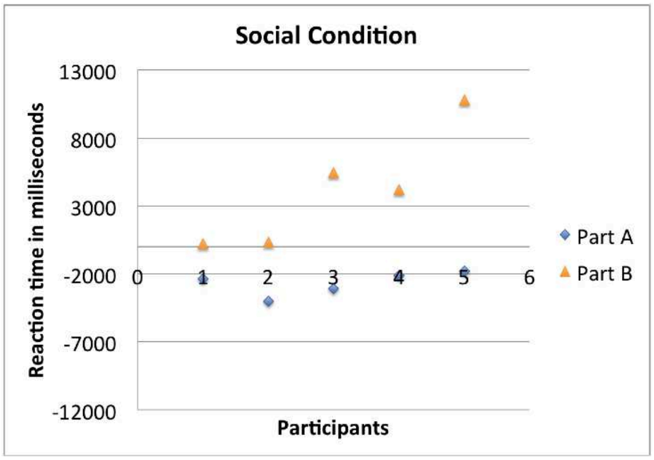

Fig. 9. Social Condition

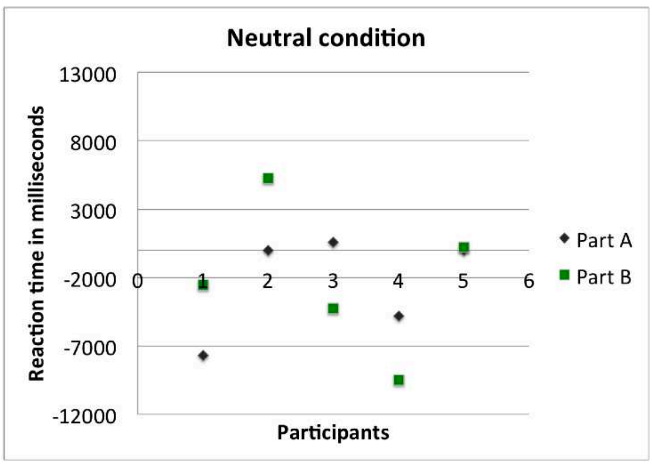

Fig. 10. Neutral Condition

V. Discussion and Conclusion

The proposed hypothesis that if the robot can mitigate disappointment due to failure to perform a task then it would be more acceptable to humans, can be supported by the findings presented in this paper. Not only that the participants liked to stay closer to the robot when it was mitigating its disappointment, but also they felt less obligated to immediately respond to the robot. Thus, one could argue they were more relaxed when the robot was behaving in a more polite manner. Hence this would support our second hypothesis that the created social order by using politeness is acceptable for the human and that it will comfort him/her in the interaction with the robot. On this point only a trend for this hypothesis was found, but we believe that with a higher number of participants this will become even stronger.

We believe this due to the fact that, when limiting the analysis to one task rather than normalising of the two tasks (message delivery and call delivery), we could strengthen the trend. Thus, by reducing the variability of presentation we could strengthen the result, this is due to the small group of participants.

For the future we will examine a larger group of participants and take a deeper look inside the single tasks carried out by the robot. The results presented above strengthen our opinion, that technical issues, which can not be fully resolved yet could be mitigated by giving feedback on the disappointment. Furthermore we want to explore other opportunities to socially signal this disappointment back to the user. Also the final social strategy could be coupled with our previous work on memory using the user presence pattern to determine and predict when is the best time for the robot to recharge itself [14].

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